# Food and Feeding Habits of the Nehu, *Stolephorus purpureus* Fowler[1]

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## INTRODUCTION

THE NEHU, *Stolephorus purpureus* Fowler,[3] comprises about 95 per cent of all the baitfish used by tuna fishermen in Hawaii. Despite the fact that this species is widely used for live-bait, the baiting grounds are highly restricted in extent throughout the main Hawaiian Islands and differ markedly in their productivity. The most important baiting areas have been mapped in a recent paper which deals with racial segregation of nehu among the main Hawaiian Islands (Tester and Hiatt, in press). It suffices here to state that Kaneohe Bay, located on the northeast side of Oahu, is the leading baiting ground in Hawaii, producing, according to statistics compiled by the Territorial Division of Fish and Game, approximately 60 per cent of the total commercial catch.

Ecologically, nehu appear to be restricted to sheltered coastal waters which are somewhat less saline than oceanic water, although the adults live without noticeable deleterious effect in baitwells of tuna boats at sea and, on occasion, have been observed outside the reefs in waters completely oceanic in composition. Inshore areas suitable for nehu are scarce around the Hawaiian Islands, and in a few of these baiting grounds the population density is often great. The importance of this species to the tuna industry, coupled with the fact that the supply available in these few areas is somewhat precarious, as evidenced by the recent decline in the nehu population in Hilo Bay, has indicated the need for an intensive study of its biology and population dynamics.

Only two brief references to the food and feeding habits of this species exist (Hiatt, 1947*a*: 241; 1947*b*: 271), but, since these do not treat this subject in sufficient detail, the present study on the food and feeding habits of adult nehu was undertaken. Fish from five different baiting areas are analyzed to ascertain if differences and similarities in food habits may be related to variations in their size and vigor. Where adequate data are available, a comparison is made between the food organisms available and the food organisms eaten throughout the year.

## METHODS

Collections of fish were made both through the cooperation of commercial fishermen and by the use of the fishery research vessels of the Hawaii Marine Laboratory and the Territorial Division of Fish and Game. With the exception of the fish taken in Ala Wai Canal and in Pearl Harbor, most fish were caught by night-baiting methods, as described by June (1951). The fish taken in the two areas mentioned were seined during early morning day-baiting operations (June, *op.cit.*).

Fish samples were obtained from Ala Wai Canal and from Kaneohe Bay during all seasons of the year. Although collections were sparse in Pearl Harbor, Honolulu Harbor, and Hilo Bay, these data are included because the consistent year-round supply of the important food organisms in a particular area in Hawaiian waters (see Tables 3 and 6) and the consistency of the organisms eaten month to

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[3] The confused generic designation of this species within the family Engraulidae has been discussed by Gosline (1951).

month in a given area (see Tables 4 and 7) result in the diet for any period agreeing rather closely with the average daily diet throughout the year. Thus, an adequate sample for a single month, while appearing scanty for year-round appraisal, has much more value in this area than it would where extensive seasonal variation is the rule. Table 1 indicates the number of fish examined each month for each locality.

The stomach of each fish was removed and opened, and the contents were washed into a Syracuse watch glass. The organisms present were identified to the most exclusive taxonomic category practicable, then counted and recorded.

For each area these calculations were made: the average percentage by number of the complete stomach contents which each type of organism constituted; the average number of organisms in the stomachs; and the percentage of stomachs containing the organism. Emphasis is laid upon percentages by number rather than upon volume. While this method is not altogether satisfactory because the size of the different food elements varies considerably, it provides the best general idea of the relative importance of the various components because of the selective method of feeding. To circumvent misconceptions arising from such treatment of data of this sort Hardy (1924: 19), dealing with food analyses of herring, gave increased values to larger organisms to compensate for larger size. This practice has not been followed in this paper, so it must be borne in mind that ghost shrimps, hyperiid amphipods, crab megalopa, and shrimps are considerably larger than copepods and barnacle larvae. Since data are presented by areas, and since the size range among food organisms taken in each area is not as great as in the food of some other species of fish, the percentages would not be greatly altered if compensation were made for variation in size of organisms. The only important difference in sizes occurs where copepod eggs are present in considerable quantity. The data for Kaneohe Bay and Pearl Harbor should be considered with this difference in mind because adult copepods are many times larger than their eggs.

In tabulating the data, the collections were grouped according to locality, and the general mean for an area was obtained by averaging the totals for the year. The results of the food analyses are summarized for Kaneohe Bay in Table 2, for Ala Wai Canal in Table 5, for Honolulu Harbor in Table 8, for Pearl Harbor in Table 9, and for Hilo Bay in Table 10. The relative importance (percentage by number) of the most important food organisms consumed in each area is diagrammed in Figure 1 so that food habits in the five areas may be compared. To assess objectively the extent to which nehu depend upon the various components of the plankton, an analysis was made of the gross aspects of the month to month fluctuation in plankton organisms in Kaneohe Bay and Ala Wai Canal (Tables 3 and 6). Possible seasonal change in food habits of nehu in these two baiting areas was determined by tabulating the food organisms present in the stomachs month by month (Tables 4 and 7).

TABLE 1

The Number of Nehu Examined Each Month for Each Locality

| LOCALITY | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kaneohe Bay...... | 4 | 8 | 10 | – | 8 | – | 5 | 12 | 19 | 6 | 8 | – | 80 |
| Ala Wai Canal..... | – | 1 | 3 | – | 56 | – | 17 | – | – | 4 | – | – | 81 |
| Pearl Harbor...... | 2 | – | – | 2 | – | – | – | – | – | 17 | – | – | 21 |
| Honolulu Harbor.. | – | – | – | – | – | – | 20 | – | – | – | – | – | 20 |
| Hilo Bay.......... | – | – | – | – | – | – | – | 20 | – | – | – | – | 20 |
| | | | | | | | | | | | | | 222 |

TABLE 2

FOOD OF NEHU (*Stolephorus purpureus*) IN KANEOHE BAY, OAHU, BASED ON AN ANALYSIS OF 80 STOMACHS

| ORGANISM | PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED | AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM | PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS |
|---|---|---|---|
| Copepods | | | |
| adults | 79 | 16 | 35 |
| eggs | 30 | 23 | 19 |
| Shrimps | | | |
| adults | 6 | 1 | TRACE |
| mysis | 29 | 19 | 15 |
| zoeae | 5 | 11 | 1 |
| Barnacle larvae | | | |
| nauplii | 25 | 20 | 13 |
| cypris | 25 | 7 | 5 |
| Crab zoeae | 25 | 12 | 8 |
| Amphipods (Hyperiidae) | 11 | 7 | 2 |
| Ghost shrimps (*Leucifer faxonii*) | 11 | 2 | 1 |
| Isopods | 4 | 2 | TRACE |
| Gastropod veliger larvae | 1 | 1 | TRACE |
| Ostracods | 1 | 2 | TRACE |
| Stomatopod larvae | 1 | 8 | TRACE |
| Fish larvae | 1 | 3 | TRACE |
| Diatoms | 3 | 4 | TRACE |

*Acknowledgments:* Personnel of the Hawaiian Tuna Packers Corporation and commercial fishermen belonging to the Tuna Boat Owners Association were very helpful in securing samples of nehu for this study. Fishery biologists employed by the Territorial Division of Fish and Game and by the University of Hawaii have been most cooperative in securing specimens for analysis. To all these individuals the writer extends his appreciation for their interest and assistance.

## ANALYSIS OF FOOD AND FEEDING HABITS

*Food organisms eaten:* Reference to Figure 1 will show certain local differences in the kinds and proportions of food items taken by nehu. Copepods—either adults, nauplii, or eggs—predominate in nehu taken in Kaneohe Bay, Pearl Harbor, and Hilo Bay, with the latter two areas much alike in the items and proportions thereof taken. In the remaining two areas, Ala Wai Canal and Honolulu Harbor, copepods are of little or no importance to nehu as food, the chief items eaten being ghost shrimps (*Leucifer faxonii*) and crab megalopa. In most cases the largest fish in a sample contained the greatest volume of food, and the stomachs of the characteristically large nehu from Ala Wai Canal and Honolulu Harbor were usually greatly distended, as compared with the rarely distended stomachs of smaller fish distinctive of other areas. The monthly distribution of food organisms taken in Kaneohe Bay (Table 4) and in Ala Wai Canal (Table 7) shows very little change during any period of the year in regard to the more important dietary items.

A comparison of the food habits of the nehu with other anchovies is not very satisfactory because so few comparable studies have been made. Similar components of the zooplankton are taken by the Mediterranean anchovy, *Engraulis encrasicholus* (Miranda y Rivera, 1930), and by a Japanese engraulid, *Coilia mystus* (Suyehiro, 1942), which has an alimentary canal almost identical with that of the nehu. However, certain fundamental differences in the diet of other anchovies are ap-

TABLE 3

Monthly Distribution of the Dominant Plankton Components in Kaneohe Bay, Oahu, Based on Routine Bi-weekly Hauls in Areas Occupied by Nehu. The Symbol xxx Denotes Great Abundance, xx Denotes Common Occurrence, and x Denotes Uncommon or Rare Occurrence

| ORGANISM | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chaetognatha (*Sagitta*) | xxx | xxx | xxx | xxx | xxx | xxx | xxx | xxx | xxx | xxx | xxx | xxx |
| Copepods (nauplii and adults) | xxx | xx | xxx | xx | xx | xxx | xx | xx | xxx | xx | xxx | xxx |
| Ctenophora | xxx | xxx | xxx | xxx | xx | xxx | xxx | xxx | xx | x | xxx | xxx |
| Shrimp larvae (mysis) | xx | xx | xx | x | x | xx | x | x | xx | x | xx | x |
| Shrimp larvae (zoeae) | xx | x | xxx | x | x | xxx | x | xx | xx | x | xx | xx |
| Crab larvae (zoeae) | xx | xxx | xxx | xxx | xx | xxx | x | xx | xxx | xxx | x | xxx |
| Ghost shrimps (*Leucifer faxonii*) | – | – | xx | x | xx | xx | xx | x | x | – | x | x |
| Barnacle larvae (nauplii) | x | xx | x | – | – | – | – | x | x | xx | xxx | xxx |
| Barnacle larvae (cypris) | – | x | – | – | – | – | – | – | – | – | – | – |
| Amphipoda (Hyperiidae) | – | x | x | x | x | x | x | xx | xx | – | – | – |
| Tunicata (Larvacea) | x | x | x | x | x | x | x | xx | x | xx | x | x |
| Gastropod and pelecypod larvae | x | x | x | x | x | x | x | – | – | – | x | – |
| Ostracoda | – | – | x | x | – | x | x | x | – | – | x | x |
| Stomatopoda larvae | – | – | x | – | – | xx | – | x | x | – | x | x |
| Isopods | x | – | – | – | – | – | – | – | x | – | – | – |
| Annelida larvae | – | x | – | x | x | – | – | – | – | – | – | – |
| Medusae | – | – | x | x | – | – | – | – | – | – | – | – |

parent. Although too few fish were examined for reliable results, Allen (1921: 543) reported the stomachs of the West Coast anchovy, *Engraulis mordax*, to contain only diatoms and dinoflagellates, and Suyehiro (1942: 54) showed the Japanese anchovy, *Engraulis japonicus*, to be exclusively a feeder on phytoplankton. Nishikawa (1901), studying this same anchovy, found that the young fed chiefly on copepods and did not specialize on phytoplankton until adulthood was attained. Correspondingly, the intestine of *E. japonicus* is much longer than that of the nehu, and it is suggestive of herbivorous rather than carnivorous habits. The lack of phytoplankton in the diet of Hawaiian anchovies might be attributed to the fact that diatoms and dinoflagellates are very sparse in the Hawaiian area.

TABLE 4

Monthly Characteristics of the Food Habits of Nehu in Kaneohe Bay. The Symbol x Denotes Occurrence in Stomach Contents

| ORGANISM | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copepods (nauplii and adults) | x | x | x | – | x | – | – | x | x | x | x | – |
| Barnacle larvae (nauplii) | x | x | x | – | x | – | – | x | x | – | – | – |
| Barnacle larvae (cypris) | x | x | x | – | x | – | – | – | – | – | – | – |
| Crab zoeae | – | – | x | – | – | – | x | x | x | x | – | – |
| Shrimps | – | – | – | – | x | – | x | – | – | – | – | – |
| Shrimp larvae (zoeae) | – | – | – | – | – | – | – | – | – | x | – | – |
| Shrimp larvae (mysis) | x | – | – | – | x | – | – | x | x | x | – | – |
| Ghost shrimp (*Leucifer faxonii*) | – | – | – | – | – | – | – | x | x | – | – | – |
| Amphipoda (Hyperiidae) | – | – | – | – | – | – | – | x | x | – | – | – |
| Isopods | – | – | – | – | – | – | – | x | x | – | – | – |
| Stomatopoda larvae | – | – | – | – | – | – | – | x | – | – | – | – |
| Fish larvae | – | – | – | – | – | – | – | – | x | – | – | – |
| Ostracoda | – | – | – | – | – | – | – | – | x | – | – | – |
| Veliger larvae | – | – | – | – | – | – | – | – | – | x | – | – |

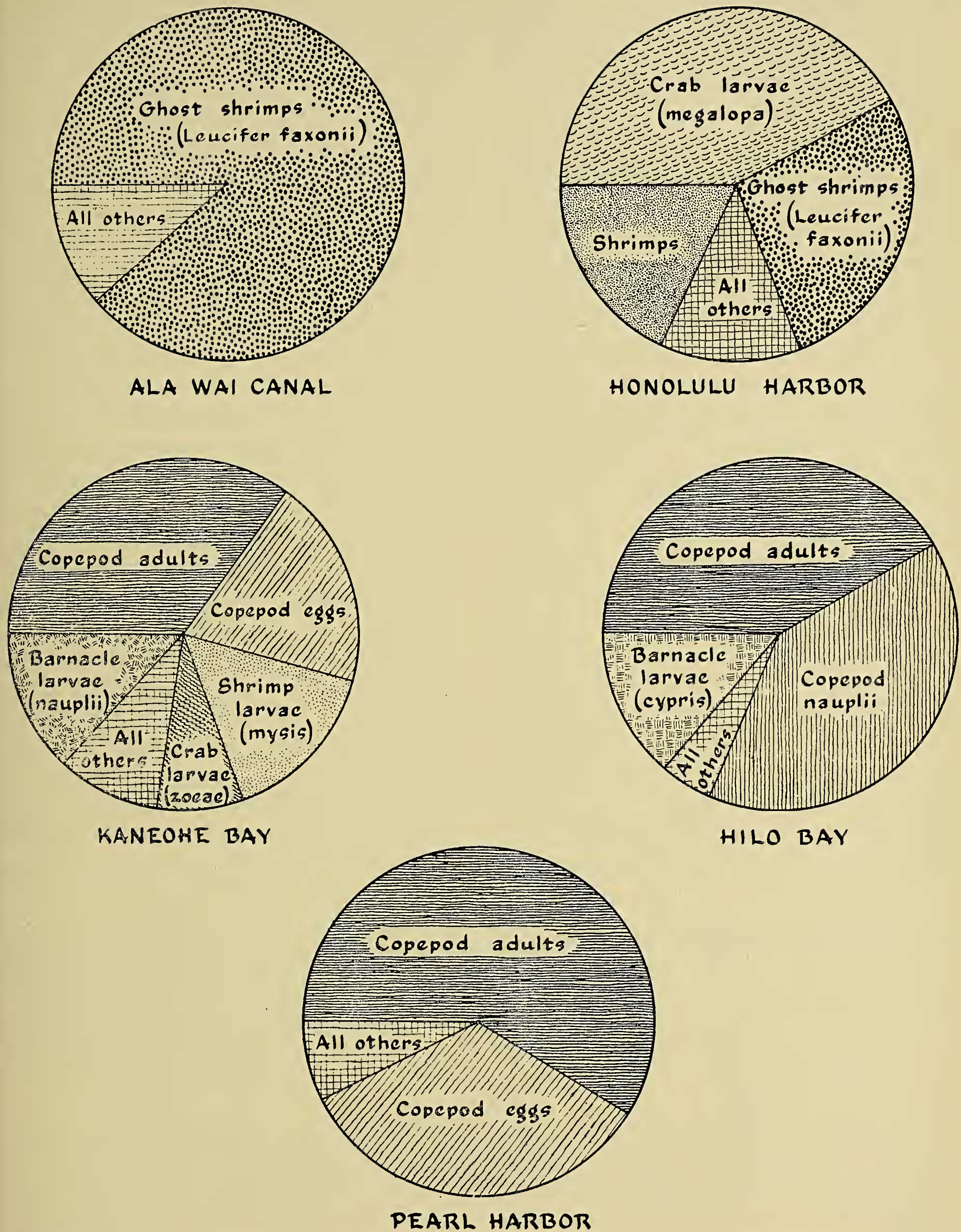


FIG. 1. Summary of the food habits of nehu from the five baiting areas investigated in this study.

The food and feeding habits of nehu and other engraulids are quite similar to those of the closely related clupeids. Herring in the North Pacific (Kuragami, 1930; Wailes, 1935), in the North Atlantic (Moore, 1898; Weber and Wilson, 1920; Bigelow and Welsh, 1925), and in European waters (Widegren, 1876; Lebour, 1924; Hardy, 1924; Jespersen, 1928; Savage, 1931, 1937; Lucas, 1936) all consume about the same components of the zooplankton as do nehu. Sardines, both in Japanese and California waters (Suyehiro, 1942), consume a good deal of phytoplankton as well as zooplankton, with the composition of the stomach contents roughly proportional to the composition of the plankton. Thus, the food habits of nehu resemble those of herring more closely than those of sardines, yet there are other anchovies which feed more like sardines than like herring.

*Selective feeding:* The question of selective feeding may best be answered by considering the feeding habits in each area for which data have been collected on available food organisms. A comparison of Tables 2 and 3 for Kaneohe Bay indicates that (1) nehu do not accept planktonic forms indiscriminately, because few plankters other than crustaceans are eaten, although the dominant components of the plankton are chaetognaths and ctenophores; and (2) nehu do take the dominant crustacean types, about in proportion to their occurrence; i.e., copepods, mysis larvae of shrimps, zoeal larvae of crabs, and nauplii of barnacles, which are the most abundant forms found in the stomach contents, also predominate in the available plankton.

A similar analysis was made in Ala Wai Canal (Tables 5 and 6) with quite different results. Here ghost shrimps predominate by far in the stomach contents, and nine out of every ten fish contained them. By comparing the data in the tables indicated above, it is clear that in this locality (1) nehu do discriminate among the total composition of the plankton, e.g., they did not contain any medusae, isopods, chaetognaths, or polychaetes, and (2) nehu do not accept the crustaceans present in the plankton in the order of their abundance. From the standpoint of organisms available, crab zoeae and barnacle nauplii exceeded by far the number of ghost shrimps present, yet the percentage composition of the food items consumed, based on the total number of organisms found in the stomachs, shows that ghost shrimps were unquestionably preferred. The smaller, but more abundant crustaceans such as crab zoeae, barnacle nauplii, copepods, and the zoeal and mysis larvae of shrimps were almost neglected, and in no case did as much as 10 per cent of the fish examined take them,

TABLE 5

FOOD OF NEHU (*Stolephorus purpureus*) IN ALA WAI CANAL, HONOLULU, BASED ON AN ANALYSIS OF 81 STOMACHS

| ORGANISM | PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED | AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM | PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS |
|---|---|---|---|
| Ghost shrimps (*Leucifer faxonii*) | 91 | 27 | 90 |
| Shrimps | | | |
| mysis stage | 5 | 15 | 3 |
| zoeae | 5 | 9 | 2 |
| Barnacles | | | |
| cypris stage | 10 | 9 | 3 |
| nauplii | 1 | 3 | TRACE |
| Copepods | | | |
| adults | 9 | 4 | 1 |
| eggs | 1 | 3 | TRACE |
| Crab zoeae | 6 | 1 | TRACE |
| Filamentous algae | 1 | 1 | TRACE |

TABLE 6

MONTHLY DISTRIBUTION OF THE DOMINANT PLANKTON COMPONENTS IN ALA WAI CANAL, HONOLULU, BASED ON ROUTINE BI-WEEKLY HAULS IN AREAS OCCUPIED BY NEHU. THE SYMBOL xxx DENOTES GREAT ABUNDANCE, xx DENOTES COMMON OCCURRENCE, AND x DENOTES UNCOMMON OR RARE OCCURRENCE

| ORGANISM | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ghost shrimps (*Leucifer faxonii*) | xxx | xxx | xxx | xxx | xx | xx | xx | x | xx | xx | xx | xx |
| Crab zoeae | xx | xx | xx | xxx | xx | xxx | xxx | xx | xxx | xxx | xxx | xxx |
| Barnacle larvae (nauplii) | xx | x | xx | xxx | xx | xxx | xxx | xxx | xxx | xxx | xxx | xxx |
| Copepods | xxx | xxx | xx | xx | x | xxx | xx | x | xxx | x | x | xxx |
| Medusae | xxx | x | x | x | xxx | xxx | xx | x | x | xxx | xx | xxx |
| Shrimp larvae (mysis) | x | x | x | x | x | xx | x | x | xx | x | xx | xxx |
| Shrimp larvae (zoeae) | xx | x | xx | x | x | xx | x | x | x | xx | x | xxx |
| Isopoda | x | – | xxx | xxx | xx | x | – | – | x | – | x | x |
| Chaetognatha (*Sagitta*) | – | xx | xx | – | – | x | x | – | x | – | – | x |
| Polychaeta | – | – | x | x | x | x | x | – | – | – | – | – |

notwithstanding their continued presence in abundance throughout the year. Of importance in understanding the differential selection of food in Ala Wai Canal is the fact that ghost shrimps are exceedingly abundant there, the population density per unit volume being many times greater than that in Kaneohe Bay. Somewhat anomalous is the apparent disregard by nehu in Kaneohe Bay of ghost shrimps and hyperiid amphipods which are available during most of the year, although in much smaller quantities than in Ala Wai Canal.

In regard to the selection of food organisms, the food habits of nehu in Honolulu Harbor (Table 8) are quite similar to those in Ala Wai Canal. Nehu here depend chiefly on the larger crustacean elements in the plankton, with crab megalopa, ghost shrimps, and small palaemonid shrimps comprising the bulk of the food. Small plankters were taken incident to larger items only by a few fish, and these plankters constituted less than 10 per cent by number of all the organisms taken. The rather small nehu from Pearl Harbor consumed mostly copepods and a smaller quantity of crab zoeae (Table 9). An analysis of the plankton (unpublished MS.) indicates that copepods comprise the most important component, with crab and shrimp zoeae ranking second and third, respectively. It is apparent that nehu in this area exercise little or no selection among the plankters except to ignore organisms other than crustaceans. No quantitative data are available for plankton in Hilo Bay, but the results of several tows made incident to a survey of pollution in the bay indicate a very low population density, and the organisms present are comparatively very small in size. No ghost shrimps, amphipods, larval shrimps, or crab megalopa were found. The minute food items found in the stomachs of fish from this area were present in about the same proportion as they occurred in the plankton. The above analyses indicate that the nehu is definitely a feeder on the

TABLE 7

MONTHLY CHARACTERISTICS OF THE FOOD HABITS OF NEHU IN ALA WAI CANAL. THE SYMBOL x DENOTES OCCURRENCES IN STOMACH CONTENTS

| ORGANISM | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ghost shrimps (*Leucifer faxonii*) | – | – | x | – | x | – | x | – | – | – | – | – |
| Copepods | – | x | – | – | x | – | – | – | – | x | – | – |
| Barnacle larvae (cypris) | – | x | x | – | – | – | – | – | – | x | – | – |
| Crab zoeae | – | – | x | – | x | – | – | – | – | – | – | – |
| Shrimp zoeae | – | – | – | – | x | – | – | – | – | x | – | – |

TABLE 8

FOOD OF NEHU (*Stolephorus purpureus*) IN HONOLULU HARBOR, OAHU, BASED ON AN ANALYSIS OF 21 STOMACHS

| ORGANISM | PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED | AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM | PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS |
|---|---|---|---|
| Crab larvae | | | |
| megalopa | 100 | 20 | 42 |
| zoeae | 25 | 10 | 5 |
| Ghost shrimps (*Leucifer faxonii*) | 70 | 18 | 27 |
| Shrimps | | | |
| adults | 40 | 21 | 18 |
| mysis | 15 | 10 | 3 |
| Copepods | 40 | 6 | 5 |
| Barnacle larvae (cypris) | 10 | 2 | TRACE |

crustacean components of the zooplankton, and that selection of crustacean types is apparent in some areas and lacking in others.

From the standpoint of selection of food items, nehu resemble herring more nearly than they do sardines. While opinion is divided on the question of selection of plankters by sardines, most investigators agree that there is little or no selection exercised (Kishinouye, 1907; Lewis, 1929; Suyehiro, 1942), but Parr (1930) believes that phytoplankton is ingested only incidentally while sardines pursue zooplankton. Overwhelming evidence for selection in the feeding of herring has been advanced by Moore (1898), Hardy (1924), Bigelow and Welsh (1925), Bigelow (1926), Jespersen (1928), Savage (1931, 1937), Lucas (1936), Wailes (1935), and Johnson (1940). It is generally agreed that herring feed by active pursuit on sight and that adult fish ignore the smallest forms of copepods even though they may be the most abundant in the plankton. The plankters selected showed nice agreement between the occurrence in the herring food and in plankton samples. These findings are comparable to those discovered for nehu. Lebour (1920: 262) aptly sums up this subject for herring and other small plankton feeding fishes, except possibly the sardine, by stating: ". . . usually each species of fish selects its own favourite food, to which it keeps, indiscriminate feeding seldom or never taking place. . . ."

*Ingestion:* To learn how nehu ingest their food, a small school was confined in a display tank into which living ghost shrimps were then placed. The fish swam quickly to the shrimps and ate them without slackening their swimming speed. When a nehu sighted a ghost shrimp to one side it would make a quick sideways movement in turning to reach the shrimp. In doing this the whole body partly turns over producing a flash from the silvery side when viewed from above. This sideways movement and silvery flash are one of the characteristic features of a school of nehu, and serve to distinguish nehu from another important baitfish, the iao (*Pranesus insularum*), during both day and night baiting operations. Captive herring have been observed to behave similarly (Johnson, 1940: 392).

*Relation of size of fish to size of food:* Length-frequency plots of nehu in the commercial catch for the various baiting areas clearly show characteristic differences in the average size of fish (unpublished data). Certain of the areas involved in this study (Ala Wai Canal and Honolulu Harbor) can always be depended upon to provide larger fish than the other areas mentioned. The nehu in Kaneohe Bay and in Pearl Harbor are characteristically small in size, with those in Hilo Bay still smaller. Obviously, factors other than food supply may operate to regulate the average size composition of a fish population, such as (1) differences in fishing intensity from one area to the next, or (2) hereditary differences in growth rate. Unfortunately, the effect of fishing intensity on the population characteristics of nehu is unknown. Furthermore, while racial segregation, as evidenced by an analysis of meristic features, has been shown between certain areas, it has not been shown for others (Tester and Hiatt, in press), so no conclusions may be drawn concerning hereditary differences in growth rate from one area to the next. We do know that (1) the average size of fish in the commercial catch differs between areas but is rather consistent within an area, (2) the composition of the plankton differs between areas but is rather consistent within an area, and (3) large nehu exercise some selection and take mostly the larger forms among the available crustacean plankters, while small nehu seem to take the smaller crustacean components in about the same proportion as they occur in the plankton. From these data certain implications may be made concerning the relation of the size of fish to the size of food.

It was noted previously that a predilection for certain abundant, large crustacean plankters and a virtual disregard for even more abundant but smaller crustacean plankters was apparent in nehu living in Ala Wai Canal and Honolulu Harbor. Both these areas produce nehu of comparatively large size. The medium-sized nehu of Kaneohe Bay and Pearl Harbor and the very small nehu of Hilo Bay do not exercise appreciable selection among the crustacean elements in the plankton. In Kaneohe Bay and in Pearl Harbor large crustacean plankters are sparse in contrast with similar forms in Ala Wai Canal and Honolulu Harbor, while in Hilo Bay large crustaceans are absent and smaller ones are sparse. Thus there appears to be a positive relationship between the size of fish and the size of crustacean plankters available, and a relationship between the size of fish and the size of crustacean plankters consumed. With regard to the former, it appears possible that nehu may not exceed a certain size unless a sufficient quantity of food of the proper type and size is available. Underlying reasons for such a hypothesis involve nutritional demands per unit of time on the part of the fish and the proportional protein content of small versus larger crustaceans, subjects on which no data are available. With food organisms ranging from minute to large sizes, available in adequate amounts, it is possible that the growth rate of nehu is sufficiently rapid to provide characteristically larger fish to the commercial catch in certain areas. Where the food supply lacks organisms beyond a certain size, growth may slacken appreciably as the fish becomes larger and nehu of characteristically smaller average size might result in other areas.

TABLE 9

FOOD OF NEHU (*Stolephorus purpureus*) IN ULUMOKU POND, PEARL HARBOR, OAHU, BASED ON AN ANALYSIS OF 21 STOMACHS

| ORGANISM | PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED | AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM | PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS |
|---|---|---|---|
| Copepods (*Acrocalanus inermis*) | | | |
| adults | 90 | 83 | 60 |
| eggs | 90 | 47 | 34 |
| Crab zoeae | 86 | 6 | 4 |
| Shrimps (*Leander debilis*) | | | |
| zoeae | 10 | 1 | TRACE |
| megalopa | 10 | 21 | 2 |
| Barnacle larvae (cypris) | 48 | 1 | TRACE |
| Ghost shrimps (*Leucifer faxonii*) | 5 | 1 | TRACE |

TABLE 10

FOOD OF NEHU (*Stolephorus purpureus*) IN HILO BAY, HAWAII, BASED ON AN ANALYSIS OF 20 STOMACHS

| ORGANISM | PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED | AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM | PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS |
|---|---|---|---|
| Copepods | | | |
| adults | 80 | 9 | 41 |
| nauplii | 55 | 13 | 40 |
| Barnacle larvae | | | |
| cypris | 80 | 3 | 14 |
| nauplii | 10 | 7 | 4 |
| Nehu scales | 30 | – | – |
| Crab zoeae | 5 | 4 | 1 |

With regard to the relationship between the size of fish and the size of organisms consumed, it is probably a function of the abundance of organisms of various sizes combined with the physical ability of the fish to catch and ingest them. Ghost shrimps are not present in the stomachs of small nehu, even in areas where these crustaceans are abundant. Large fish in areas where large crustaceans are abundant in the plankton naturally select them over small crustaceans because they can ingest organisms of larger size and their nutritional requirements would probably be fulfilled in less time and with less energy expended. Fish in areas lacking larger crustacean plankters have no choice in the matter.

*Relation of food to vigor:* Fishermen are cognizant of the differences in the characteristic vigor of nehu caught in the various baiting areas. The small fish from Hilo Bay and Kaneohe Bay seem less able to withstand the handling and confinement required in catching, transferring, and transporting them to the tuna fishing areas than are the larger and more vigorous fish taken in Ala Wai Canal and Honolulu Harbor. While we have no data which would compare vigor in small and large fish in the same baiting area, it is possible that vigor is directly related to the size of the fish. Small herring, for example, are more fragile and less hardy than large herring because they lose their scales more readily. Some evidence that hardiness in nehu may resemble that for herring was found by examining the stomach contents of nehu caught in Hilo Bay. Approximately one-third of the fish stomachs contained nehu scales. The shiny scales were sighted and ingested as they were shed into the water. The taking of scales would be only of academic interest if it were not for the fact that Hilo Bay nehu are very small, exceedingly fragile and weak, and difficult to maintain alive in bait wells. If these small nehu lose their scales more readily than do larger nehu, as is true for herring, the excessive fragility may be associated with the small size. Although we have insufficient evidence at present, further study on the relation of vigor to size and of size to food available may indicate the principles underlying the apparent differences in size and vigor of nehu in the various baiting grounds.

## SUMMARY

Investigations into the food and feeding habits of the nehu, the leading livebait fish for tuna in Hawaiian waters, were conducted for five important baiting areas in Hawaii. A total of 222 stomachs of fish from the commercial catch was analyzed for food contents. A gross quantitative analysis of the principal plankton species present in two areas was made for a comparison between the food items consumed and the organisms available.

Copepods, barnacle nauplii, and mysis larvae of shrimps were most important in the diet of nehu taken in Kaneohe Bay; ghost shrimps (*Leucifer faxonii*) predominated in

fish from Ala Wai Canal; in Honolulu Harbor nehu food was mostly crab megalopa, ghost shrimps, and small palaemonid shrimps; and copepods predominated in stomach contents of nehu from Pearl Harbor and Hilo Bay. Very little seasonal change occurs in the kinds and proportions of the more important dietary items.

Nehu are selective feeders in that they take only the crustacean elements in the plankton. Selection among certain crustacean types is apparent in some areas and is lacking in others.

The characteristically larger nehu in Ala Wai Canal and in Honolulu Harbor show a predilection for large crustacean plankters and a virtual disregard for the more abundant smaller crustacean types, whereas the usually smaller nehu of other areas ignore the few large types available and consume the smaller forms in about the same proportions as they occur in the plankton. The baiting areas which have an abundant supply of the larger crustacean elements in the plankton contain the largest fish, while those areas which support only a sparse population of these larger plankters, or none at all, contain the smallest fish.

Further study on the relation of vigor to size and of size to food available may indicate the principles underlying the apparent differences in size and vigor of nehu in the various baiting grounds.

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